No-tillage Transplanting System of Rice with Controlled Availability Fertilizer in a Nursery Box : Nitrogen Use Efficiency of Controlled Availability Fertilizer of Rice Plant in Three Different Paddy Fields

No-tillage Transplanting System of Rice with Controlled Availability Fertilizer in a Nursery Box
-Nitrogen Use Efficiency of Controlled Availability Fertilizer of Rice Plant in Three Different Paddy Fields-

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key words : nitrogen-use efficiency, no-tillage transplanting system, 15N sigmoid type of polyolefin-coated urea, soil types

Abstract

The fate of polyolefin ^{15}N coated urea (POCU S-100) in a nursery box for the no-tillage transplanting system as compared with ^{15}N ammonium sulfate (AS) in the conventional tillage system had been investigated in light clay alluvial soil, sandy loam alluvial soil, and clay loam soil (Andisol) in 1994 and 1995. Rice (Oryza sativa L. cv. Hitomebore) was used as the test plant.

The nitrogen concentration of the leaf blade of the rice plant in the no-tillage without rice straw (NT) and no-tillage with rice straw (NTS) treatments tended to be greater than those of the conventional tillage with rice straw (CTS) treatments in all types of soil at all growth stages, and there was no definite increasing or decreasing tendency in the N concentration of the leaf sheath and stem, and panicles of the rice plant among the treatments in all types of soil. Nitrogen recoveries from POCU S100 in the NT and the NTS systems were 77-79% and 78-83%, 61-73% and 66-78%, and 74-76% and 80-81% for light clay soil, sandy loam soil and clay loam soil, respectively, which is around 65.5-96% of the nitrogen released from POCU S100. Thus, this could reduce the environmental pollution. The straw application in the NT system increased the N recovery of POCU S-100 by 1-5%. On the other hand, nitrogen recoveries from ammonium sulfate applied as basal fertilizer in the CTS system were 35-43%, 20-29% and 23-32% for light clay soil, sandy loam soil and clay loam soil, respectively. Whereas those applied as a top dressing were 50-83%, 49-73% and 40-65%. Nitrogen uptake by the rice plant in the NT system was relatively higher than that in the CT system. The uptake of soil nitrogen by the rice plant in the NT system was lower than that in the CT system.

Introduction

Nitrogen is the most important nutrient element in controlling rice production worldwide. However, farmers usually apply an excessive amount of readily available nitrogen fertilizers for the NT transplanting system in order to stimulate fast development of the rice during the early growth stage and to obtain high yield. However, this may be disadvantageous in terms of its recovery. Because of such fertilizer practices, the recovery of nitrogen from the fertilizer with a basal application in the surface layer is very low (<10%) (Kaneta, 1995), and these practices promote N losses, especially through leaching and denitrification (Alison, 1966; Rao and Prasad. 1980). These losses of fertilizer N lead to an increased concentration of nitrous oxide in the tropospheric atmosphere and contribute to destruction of the stratospheric ozone layer (Bremner and Blackmer, 1978). Multiple-split applications of N fertilizer can reduce N losses (De Datta and Buresh, 1989), but this increases operating costs as well. Alternatively, controlled availability fertilizer (CAF) developed in Japan shows a much higher recovery compared to readily available fertilizer. A single basal application of the total N fertilizer as a CAF can supply enough N to the rice crop for the whole duration of the growth period in order to achieve satisfactory grain yield. By using a sigmoid type of CAF with 100 days release in the NT transplanting system of rice, polyolefin-coated urea (POCU S100) in a nursery box had been practiced; however, literature providing data ^{15}N-POCU S100 and rice under different field conditions is limited (Kaneta, 1995). Several cultivation practices in northeastern Japan has shown a superior yield potential in the NT transplanting system with POCU S100 in a nursery box over conventional tillage practices in clay soil. However, soil and climatic conditions can influence the growth and yield of rice, the mineralization of soil-organic nitrogen and the absorption of fertilizer and soil nitrogen by the rice plants. Although, the accumulation and distribution of N in the vegetative and reproductive organs of rice are important processes in determining grain yield (Norman et al., 1992). However, absorption and accumulation of N varies with the development stages of the rice crop. Maximum N demand periods occur during active tillering and early reproduction, with absorption being near completion by panicle emergence (Wada et al., 1986; Wilson et al., 1989). Schnier et al. (1990) reported that plant N status, beginning at panicle initiation, influences spikelet differentiation and, thus, yield potential. Therefore, the objectives of this experiment are to determine the efficiencies of POCU S100 by rice at the young panicle initiation stage and at harvest time in the no-tillage transplanting system and to compare these with different soil types at the same stages.

Materials and Methods

Field ^{15}N experiments were conducted in 1994 and 1995 on light clay and sandy loam alluvial soil at Furukawa (flat area) and clay loam Andisol at Kawatabi (hilly area), Miyagi Prefecture, Japan. The properties of these soil types and the climatic conditions during the growing season of the rice have been reported in the previous paper (Hossain et al., 2000). Rice (Oryza sativa. L. cv. Hitomebore) was used as a test crop. Three treatments, conventional tillage with straw (CTS), no-tillage without straw (NT) and no-tillage with straw (NTS) were tested through three replications. For this experiment, 0.09 m^2 (30 cm x 30 cm) micro plots were set with metallic frame in the main fields. Land preparation had been reported in the previous paper (Hossain et al., 2000).

Sigmoid type of ^{15}N POCU (Polyolefin Coated Urea) S100 (3.24 atom % ^{15}N) as a source of CAF was used as a single basal application of total nitrogen at the rate of 7 g N m^{-2} in a nursery box at the time of sowing for the NT treatments. In the CTS treatment, readily available ^{15}N AS (3.03 atom % ^{15}N), supperphosfate and KCl were applied at the rate of 5 g N m^{-2} at the transplanting time as a basal source of N, P_2O_5 and K_2O. ^{15}N AS of 1 g N m^{-2} was top dressed twice at 15 and 25 days before heading for the CTS treatment. Three micro plots were used per treatment and each micro plot contained two hills of rice. Five seedlings were transplanted from each hill.

At the young panicle formation stage (12 July) and at harvest, plants from three micro plots per treatment were sampled and separated into leaf blade, leaf sheath and stem, and panicles. Each part was oven-dried at 70 oC for 48 h and weighed. The total N of each part of the plant (leaf blade, leaf sheath and stem, and panicles) was determined by the method of Bremner and Malvaney (1982). The ^{15}N content of samples were analyzed by the JASCO ^{15}N analyzer (MODEL N-151). Statistical differences in the results among the treatments were determined by Least Significant Difference (LSD) at a 5% level of significance.

Results and Discussion

Nitrogen concentration and partitioning

The N percentages of each part of the plant at the young panicle initiation stage and at harvest time in 1994-1995 are shown in Table 1. The N concentration of each part of the plant at the young panicle initiation stage was higher than that at harvest time. Sims and Place (1968) and Yoshida (1981) have reported that N concentration of the rice plant was directly related to the age of the plant, which is high in the early growth stage and declining towards maturity. The N concentration of the leaf blade of the rice plant in NT and NTS treatments tended to be greater than those in the CTS treatments. And there was a clear tendency for the N concentration to increase in the leaf blade of the rice plant in the NTS treatments more than that in the NT treatments. This may serve as an important source of N for the next cropping season. However, there was no definite increasing or decreasing tendency in the N concentration of the leaf sheath and stem of the rice plant among the treatments in all soil types (Table 1). The N concentration of the panicles of the rice plant was almost the same among the treatments in all soil types.

Table 1. Nitrogen percentage of each part of rice plant at young panicle initiation stage and at harvest time

Type of soil	Treatment	Panicle initiation stage				Harvest time					
		Total N (%)				Total N (%)					
		Leaf blade		Stem and leaf sheath		Leaf blade		Stem and leaf sheath		Panicle	
		1994	1995	1994	1995	1994	1995	1994	1995	1994	1995
Light clay (Alluvial soil)	NT	3.56	3.44	1.46	1.61	1.10	1.13	0.44	0.42	0.99	1.07
	NTS	3.19	4.30	1.66	2.01	1.27	1.36	0.38	0.48	0.95	1.17
	CTS	2.94	3.24	1.66	1.51	0.88	1.00	0.38	0.41	1.00	0.92
	LSD at 5%	0.501	0.373	-	0.249	0.187	0.095	-	-	-	0.10
Sandy loam (Alluvial soil)	NT	3.19	3.15	1.22	1.37	1.18	1.14	0.46	0.54	1.13	1.05
	NTS	3.79	3.65	1.34	1.35	1.30	1.38	0.62	0.53	1.08	1.34
	CTS	3.89	2.51	1.32	1.31	1.08	1.16	0.47	0.55	1.03	1.20
	LSD at 5%	0.312	0.486	-	-	0.15	0.11	0.043	-	-	-
Clay loam (Andisol)	NT	3.13	3.72	1.63	1.63	1.40	1.50	0.52	0.44	1.17	1.01
	NTS	3.40	3.83	1.37	1.58	1.56	1.55	0.86	0.54	1.26	1.07
	CTS	3.50	3.31	1.87	1.37	1.53	1.16	0.48	0.44	1.28	1.07
	LSD at 5%	0.031	0.373	-	-	-	0.25	0.275	-	-	-

NT – No–tillage without rice straw NTS – No–tillage with rice straw
CTS – Conventional tillage with rice straw
LSD – Least significant difference

Recovery of controlled availability fertilizer

Recoveries of POCU S-100 N in the NT and NTS treatments in comparison with AS in the CTS treatments are shown in Fig.1 and Fig. 2. In 1994, at the young panicle formation stage (12 July), the N recoveries of POCU S-100 in the NT and NTS treatments were 46.1 and 44.2%, 41.0 and 44.8%, and 44.9 and 42.5 % in light clay soil, sandy loam soil and clay loam soil (Andisol), respectively, whereas, the recoveries of basal ammonium sulfate N were 43.1%, 32.8% and 31.1%, respectively. On the other hand, in 1995, the results in the NT and NTS treatments were 38.3 and 40.5 %, 36.7 and 40.0%, and 39.1 and 39.6 % in light clay soil, sandy loam soil and clay loam soil (Andisol), respectively; whereas the recoveries of basal ammonium sulfate N in the CT treatment were 38.8%, 21.4% and 23.0%, respectively. Namely, the difference of recoveries between the three soil types was much higher in the CTS treatments than in the NT treatments (Fig. 1). In 1994, at the harvest stage, the N recoveries in the NT and NTS treatments were 76.6 and 78.3%, 61.4 and 66.2%, and 74.2 and 80.0% in light clay soil, sandy loam and clay loam soil (Andisol), respectively, which were around 66–96 % of the nitrogen released from CAF at harvest time. On the other hand, in 1995, the results in the NT and NTS treatments were 78.8 and 82.7%, 72.8 and 77.6%, and 75.8 and 81.1% in light clay soil, sandy loam soil and clay loam soil (Andisol), respectively, which were around 84.6–96.2 % of the nitrogen released from CAF at harvest time. Kaneta (1995) reported that the recovery of the POCU S -100 in heavy textured, poorly drained clay soil was 79% at the maturing stage. The recoveries of CAF in the NTS treatments at harvest time were 1–5% greater than those in the NT treatments. It seems that the rapid decomposition of straw in the NT system may cause temporary immobilization of fertilizer N by promoting the microbial activity in the early growth stage. However, in the long run, there will be an increase in the contents of soil ^{15}N due to mineralization of ^{15}N fixed by microorganisms. However, the recoveries of basal ammonium sulfate N at harvest time were almost the same as they were at the young panicle formation stage. The recoveries of top-dressed AS were 40.0 – 76% in the 1st top dressing and 43 – 82.7% in the 2nd top dressing which were much higher than those in the basal application. The recoveries of ammonium sulfate were higher in the 2nd top dressing than in the 1st one, and those in clay alluvial soil were much higher than those in sandy alluvial soil and clay loam soil (Andisol) reflecting on the different drainage conditions and cation exchange capacity as are shown in the previous paper (Hossain et al., 2000). Takahashi et al., (1976) reported that almost all of the N disappeared at the commencement of ear-primodia formation, and the recoveries of basally applied N are generally about 30%. On the other hand, top-dressed N are absorbed rapidly within a week after application because the rice plant has already developed an extensive root system by the time of the top dressing. Therefore, the recoveries of top-dressed N are generally about 50% (Shoji and Gandeza, 1992).

Nitrogen uptake from soil and fertilizer

Nitrogen uptake by the rice plant is affected by N concentration and dry matter production. The N absorbed by the rice plant from the soil and fertilizer at the young panicle formation stage and at harvest time in 1994 and 1995 are shown in Fig. 3 and Fig. 4. In 1994, N absorbed by the rice plant in the NT and NTS treatments were lower than those of the CTS treatments in light clay soil, but they were statistically the same at harvest time. In 1995, the N absorbed by the rice plant in the NT and NTS treatments were significantly greater than those in the CTS treatments at the young panicle formation stage. However, they were statistically the same at harvest time. In 1994 and 1995, the N absorbed by the rice plant in the NTS treatments was almost the same as in the NT treatments.

In sandy loam soil, there were no significant differences among the total absorbed N of the rice plant in each treatment in 1994 at both stages. However, in 1995, the N absorbed by the rice plant in the NT and NTS treatments were statistically greater than those in the CTS treatments at both stages (Fig. 3 and 4).

In clay loam soil, there were no significant differences among the total absorbed N of the rice plant in each treatment of both years at the young panicle initiation stage. However, at harvest time, the total absorbed N of the rice plant in the NT and NTS treatments were greater than those in the CTS treatments in both years.

In 1994, the N absorbed from soil at the young panicle formation stage in the CTS treatments of all types of soil were greater than those of the NT or NTS treatments. However, opposite results were obtained in light clay soil and sandy loam soils in 1995. At the harvest stage, the N absorbed from soil in the NT and NTS treatments was relatively lower than in the CTS treatment of all soils types, and the absorbed soil N of all treatments in all soil types in 1994 was greater than those in 1995 reflecting on the climatic conditions (Hossain et al., 2000). Phillips et al., (1980) reported that the native soil nitrogen of the NT system has a lower mineralization rate as compared to conventional tillage and the soil temperature in the NT system is lower than that in the CT system. However, higher soil temperature can hasten the mineralization rate of soil nitrogen.

The total nitrogen absorbed from ammonium sulfate (AS) in the CTS treatments of light clay soil, sandy loam soil and clay loam (Andisol) were 3.76 and 2.74, 2.85 and 2.03, and 2.86 and 1.96 g /m2 in 1994 and 1995, respectively, whereas nitrogen from POCUS -100 in the NT and NTS treatments were 5.36 and 5.52, 4.30 and 5.10, 5.19 and 5.31, and 5.48 and 5.79, 4.63 and 5.43, 5.60 and 5.68 g/m2, respectively, which were about two folds greater than nitrogen from AS. The total nitrogen absorbed from soil was about 50% more than the total nitrogen absorbed. Koyama (1971) and Broadbent (1978) have reported that fertilized rice obtains 50%-80% of its N requirement from the soil.

These results indicate that the application of CAF in a nursery box for the NT system increases the recoveries of fertilizer nitrogen by the rice plant in each type of soil compared to basal AS-N in the CT system, and thus could reduce environmental degradation caused by nitrogen fertilizer and have an effect on the growth and yield of the rice plant in different paddy fields.

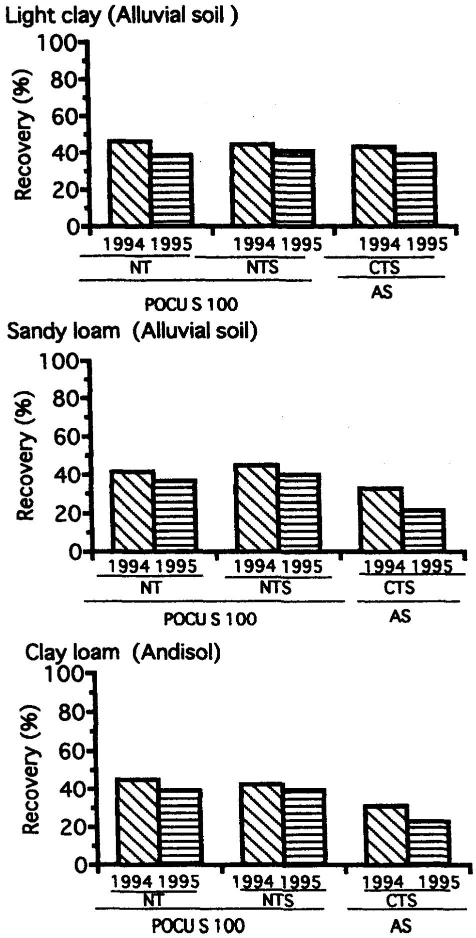

Fig. 1. Recoveries of fertilizer nitrogen by rice plants at young panicle initiation stage
NT-No-tillage without rice straw;NTS-No-tillage with rice straw; CTS-Conventional - tillage with rice straw; POCU S -Sigmoid type of Polyolefin Coated Urea; AS- Ammonium sulfate

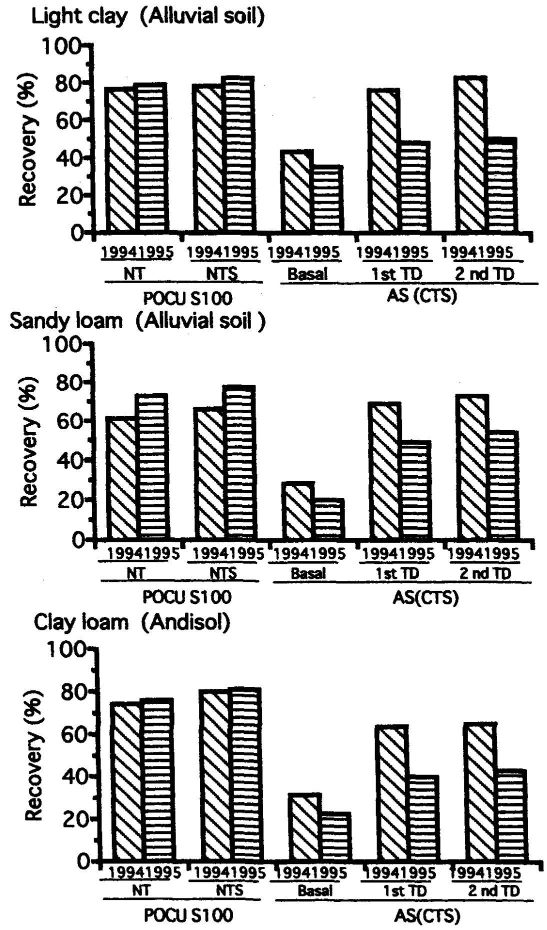

Fig. 2. Recoveries of fertilizer nitrogen by rice plants at harvest time
NT-No-tillage without rice straw;NTS-No-tillage with rice straw; CTS-Conventional - tillage with rice straw; POCU S -Sigmoid type of Polyolefin Coated Urea; AS- Ammonium sulfate;TD-Top dressing

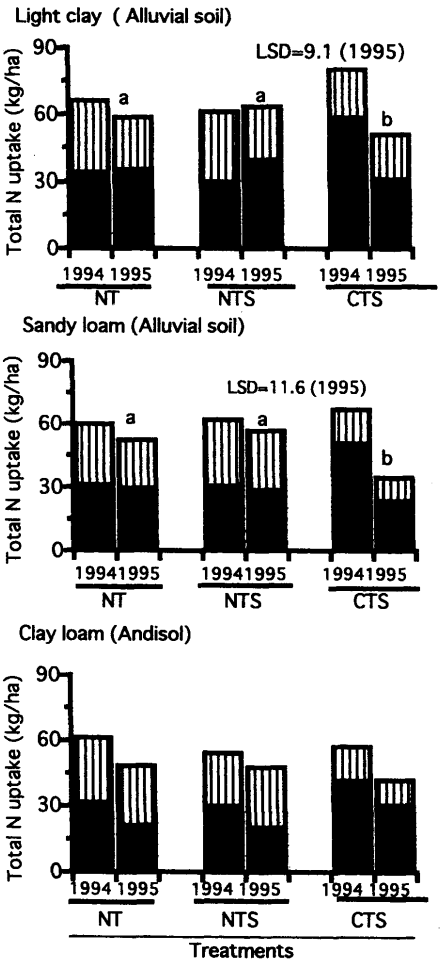

Fig.3. Nitrogen uptake of rice plant from soil and fertilizers at young panicle initiation stage
CTS- Conventional tillage with rice straw; NT - No-tillage without rice straw; NTS-No-tillage with rice straw

Fertilizer-N Soil-N

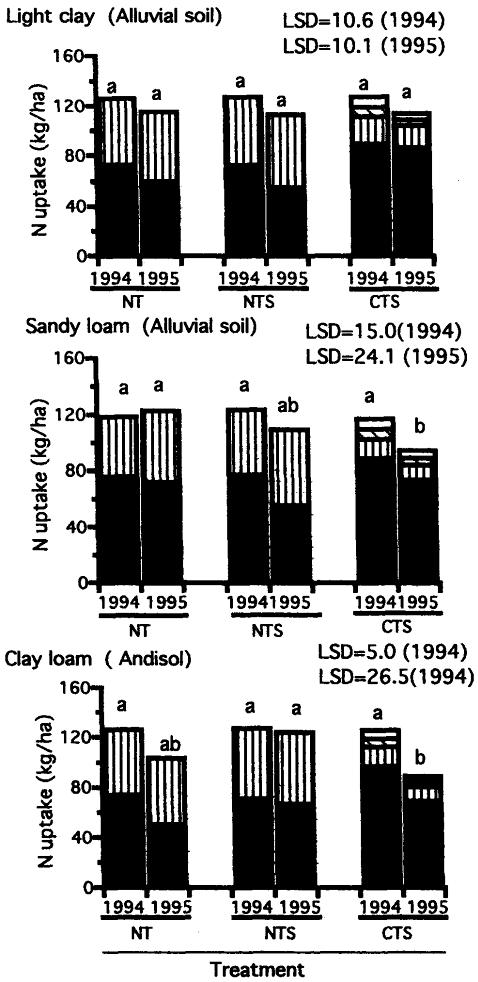

Fig.4. Nitrogen uptake of rice plant from soil and fertilizer at harvest time
NT - No-tillage without rice straw; NT-No-tillage with rice straw
CTS- Conventional tillage with rice straw;

2nd top dressing 1st top dressing Fertilizer-N Soil-N

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